

Phase-Stable, Low-Phase-Noise Filters for Reference Signals

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Reference signals may be filtered by use of the phase-locking filter described which locks the phase of the output signal to the phase of the input signal. A very small phase drift may be achieved over a large temperature range without the use of temperature-controlled ovens, which are bulky and costly.

Filters were needed to clean up the outputs of the frequency dividers used in the hydrogen maser frequency standard. It was required that the filters have a low rate of phase drift with temperature as well as a small absolute phase shift.

Three methods of meeting the requirements were considered. The filter could have been stabilized by the use of temperature-compensating components, temperature-controlled ovens, or a scheme to phase-lock the output to the input.

Temperature compensation was impractical because of the stringent requirements; however, either of the two alternative methods would give satisfactory results. Although the best stability can be obtained with temperature-regulated ovens, they are undesirable because they are bulky and costly, and require a great deal of power.

Adequate stability was achieved in less space, with lower power consumption, and at less cost by use of the phase-locked filter described (Fig. 1). The input network of the filter is a lumped-circuit equivalent of a quadrature hybrid having two output signals of equal amplitude with a 90-deg phase difference and greater than 35 dB isolation between them. One signal goes through a voltage-tunable LC filter which is used as a voltage-controlled phase shifter having a range of $\sim \pm 60$ deg. The signal is then amplified, further filtered, and split into two equal, isolated, in-phase outputs, one of which goes to the distribution amplifier. The other output goes to a phase detector, where it is compared to the remaining output from the quadrature hybrid input network. The output of the phase detector is amplified with a low-noise, integrated circuit, operational amplifier and applied to the voltage-controlled phase shifter, which in turn cancels any phase variations between the input and output of the phase-locked filter.

A tuned amplifier was used in the loop, which gave the required filtering, better efficiency, and the required source impedance for best isolation in the power splitter. Phase drift due to the tank circuit changing with temperature was cancelled by the feedback loop.

The phase change caused by a 0 to 50°C change in temperature was measured to be ~ 0.5 deg, of which the major contribution was the drift in the phase detector.

The single-sideband phase noise of the complete filter is 140 dB below the carrier in a 1-Hz bandwidth 10 Hz from the carrier. This measurement was made using the method explained in Ref. 1.

Filters were breadboarded at 5, 10, and 20 MHz, with nearly identical phase drift and phase noise for the conditions described.

Reference

1. Meyer, R., and Sward, A., "Frequency Generation and Control: The Measurement of Phase Jitter," in *The Deep Space Network*, Space Programs Summary 37-64, Vol. II, pp. 55-58. Jet Propulsion Laboratory, Pasadena, Calif., Aug. 31, 1970.

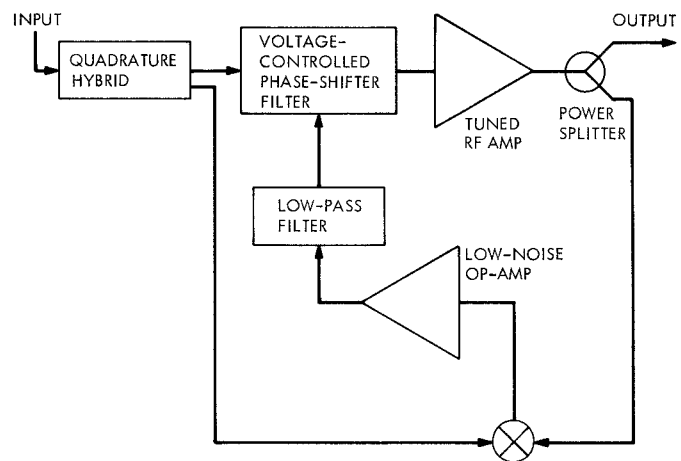


Fig. 1. Block diagram of typical filter